Radionuclide and Heavy Metal Distribution in Recent Sediments of Major Streams in the Grants Mineral Belt

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Research Objective

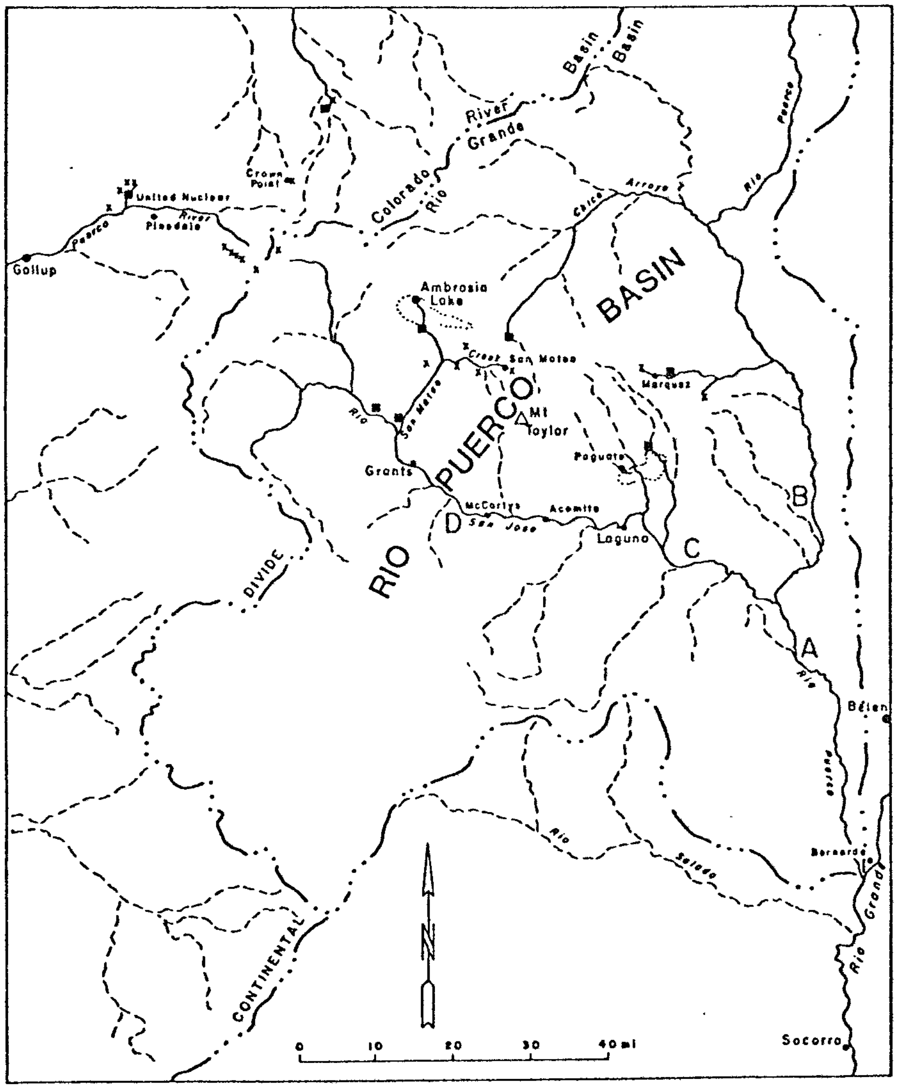
The major objective of this research proposal is to determine the extent to which active uranium mining and milling operations ~~in~~ the Grants Mineral Belt of west-central New Mexico may be contributing excess trace metals and radionuclides to Rio Puerco and Rio San Jose sediments. The Rio Puerco and Rio San Jose are ephemeral and intermittent streams which drain the active uranium mining area east of the Continental Divide. Episodic major floods deliver large quantities of sediments derived from the region of uranium mineralization and mine-mill activity downstream to the Bernardo-Elephant Butte reach of the Rio Grande. Sediment delivery is very efficient because flood flows are largely transmitted through a regional system of channels confined in arroyo-type valleys. Available historical data on Puerco-San Jose channel behavior permits indentification and sampling of stream sediments that both predate and postdate onset of uranium mine-mill operations. In order to determine trace metal and radionuclide contributions from the uranium industry during the past thirty years, the processes of sediment transport and the age of sediments tested must be established. Therefore, subsidiary objectives of this proposal include (1) determination of the modes of sediment movements in the San Jose-Rio Puerco drainage systems and (2) determination of the age of deposits along and adjacent to the modern drainage channels. Comparison of sediments deposited within the past 30 years with earlier sediments from the same area will establish man-induced contributions to sediments and will provide long-term baseline data on behavior of the affected drainage system.

Procedures

Figure 1 shows the study area, including the Rio Puerco-Rio San Jose watershed of the west-central Rio Grande basin and relationships between major streams and uranium mine-mill activity. Procedures to be used to determine the processes of sediment transport and deposition, the ages of sediments, and the trace metal-radionuclide content of the sediments include the following categories:

(1) geomorphic evaluation of the fluvial transport and depositional system from the uranium mines and mills in the headwaters through the Rio San Jose-Rio Puerco drainage systems, and evaluation of loci of sediment deposition along the drainages;
(2) historical documentation of loci of deposition to aid in determining the age of sediments;
(3) field sampling and sediment characterization along the drainages;
(4) laboratory characterization of grain size and grain mineralogy of sediment samples;
(5) laboratory determination of trace metals and radionuclide concentrations in sediments; and
(6) laboratory determination of ages of sediments using radioactive Cesium-137 (Cs-137) and Lead-210 (Pb-210).

geomorphic - of, or like the earth, its shape, or surface configuration



Drainage basin boundaries
Streams draining areas of uranium mine-mill operations
x Major uranium mines in Morrison Formation
Area with large number of major mines
■ Uranium mills (operating and planned)
See Chapman and others (1979) for details on mine-mill activity and geologic setting

Fig. I

Index map of the Grants Mineral Belt in the Rio Puerco Basin region showing sites of uranium mine-mill operations and major streams of the Rio San Jose-Rio Puerco-Rio Grande system.

Geomorphological Procedures

The general sources and transport directions of sediments can be determined by examination of maps and aerial photographs and by field reconnaissance of the drainage basins. The study area (Fig.1) includes not only major uranium mine-mill activity but also extensive outcrops of uranium-bearing rocks, mainly the Jurassic Morrison Formation (Chapman and others, 1979). Ephemeral and intermittent reaches of the Rio Puerco-Rio San Jose stream system drain the active uranium mining area east of the Continental Divide. Episodic major floods deliver large quantities of sediments derived from the region of uranium mineralization and mine-mill activity to the Rio San Jose and Rio Puerco, and ultimately to the Bernardo-Socorro-Elephant Butte reach of the Rio Grande. Sediment delivery is very efficient because flood flows are largely transmitted through a regional system of channels confined in arroyo-type valleys (Happ, 1948). Geomorphological examination of reaches of the Rio San Jose and Rio Puerco can identify past and present areas of deposition and the types of sedimentary deposits (facies) in each area.

Historical Procedures

Ages of deposits can be determined along some sections of these streams by examining compilations of historical records (e.g., Betancourt, 1980). Surveyors' notes, historical accounts, and photographs, particularly aerial photographs, indicate changes in channels and shifting areas of erosion and deposition through time. The historical data, along with geomorphological analyses, aid in selecting sample sites. For example, aerial photographs taken in 1935-36, 1947, 1951, 1953, 1962, and 1975 provide the best documentation of modern erosion-sedimentation events in the Puerco-San Jose system. Preliminary study of these photographs and 1:24,000 scale topographic maps (1947 and 1951 photo base) shows that a number of stream meanders have been isolated from active channel flow by oxbow cutoffs in the decade prior to the onset of uranium mining in the early 1950's. Therefore samples from basal deposits in these cutoff channels should provide baseline information on the sediment geochemistry before mine-mill activity.

Field Sampling Procedures

Field investigations and sediment sampling will be done along representative reaches of the Rio Puerco and Rio San Jose located east and south of Mount Taylor and downstream from the major mine-mill sites in the Grants Mineral Belt. These reaches are in four general areas (Figure 1): A. Rio Puerco below its confluence with the Rio San Jose; B. Rio Puerco above its confluence with the San Jose; C. Rio San Jose above its confluence with the Rio Puerco (downstream from Laguna); and D. Rio San Jose downstream from Grants (above Acomita).

Areas A to C are characterized by narrow channel and floodplain belts within a major arroyo system, which is deeply incised (5-15m) below broad valley floors. These entrenched reaches contain active and abandoned channel segments with sediments whose age ranges may be established by use of historical records (Betancourt, 1980). Area D also includes entrenched reaches, but it is mainly a marshy floodplain (without deep arroyos) where the valley floor near McCartys is partly occupied by young basalt flows. This area between Grants and Laguna serves as a natural trap for much of the sediment produced from the Grants Mineral Belt west of Mount Taylor.

Selection of sampling sites will be based on field inspection and on the study of photographs, maps and other historical data on river channel positions. Each sampling site will be mapped in detail (about 1:2,400), based on borehole and outcrop information, in order to establish the validity of geochemical sample point selection.

Cores for geochemical and sedimentological analyses will be collected with a 7 cm diameter bucket auger. This hand-operated coring device can drill to depths exceeding 3 meters, allowing samples to be taken at small (about 10 cm) intervals as the core hole is deepened. The integrity of each 7-12 cm section can be maintained even though the unconsolidated (sand, silt, and clay) materials are partly disaggregated during the coring operation. The character of each sample (20 to 30 per 3m core boring) will be recorded and the sample stored in double plastic bags. The large sample size (1.5-2kg) will allow many tests to be performed on each sample if necessary.

Older valley fill will also be collected from the inner (arroyo) valley walls to determine the properties of 19th century and earlier sediments, as well as to help establish the amount of supported (background) Pb-210. These deposits have not been subjected to wetting or sedimentation by mainstream flood events since deep arroyo incision in the late 19th Century.

Benchmarks will be left at the sample sites to record future changes in channel position and sedimentation rate.

Laboratory Characterization of Sediment Texture and Mineralogy

Test cores from the Rio Puerco indicate that the sediments range from pebbly sand to clay, as a result of fluctuating conditions of water and sediment discharge. The sediments consist of sequences of alternating sand, silt and clay layers. Both wet and dry mechanical techniques will be used to separate the samples into their different size fractions. The size fractions will be chemically analyzed if radioactivity is high in order to correlate heavy metals with both age and size fraction. The types of clay and non-clay minerals present in the clay-size fraction will be determined by x-ray diffraction analysis.

Chemical Analyses

Samples from selected sections of each core will be split, dried at 80°C, and digested in Teflon-lined Parr pressure bombs with nitric and hydrofluoric acids (Bernas, 1972). Trace metals associated with increased uranium mining and milling activity, such as uranium, selenium, arsenic, vanadium and molybdenum, will be determined using a Perkin-Elmer 403 atomic absorption spectrophotometer with an HGA 2000 graphite furnace and an electrodeless discharge lamp system for increased sensitivity for arsenic and selenium. Other metals may also be determined, as dictated by studies now in progress on surface waters and present suspended sediments (Brandvold, Brandvold and Popp, 1980).

Because clays have the ability to adsorb significant quantities of metal ions (Manahan, 1979), special attention will be given the clay-size fractions of the sediment samples. Cs-137 has been shown to be preferentially adsorbed by clay minerals (Jenne and Wahlberg, 1968) and it is possible that lead may also behave in this manner.

Sediment Dating Techniques

The isotopes Cs-137 and Pb-210 are of primary importance in establishing the age of these youthful sediments, and particularly in establishing whether the sediment samples predate or postdate the onset of mining activity.

Cs-137 is an artifical isotope with a half-life of 30 years, and has been added to surface sediments through atmospheric nuclear testing. The amount of Cs-137 added has varied from year to year, and reached a maximum during the periods of greatest atmospheric testing in 1958 and 1963 (Krishnaswami and Lal, 1978). Studies of sediment cores in lakes, estuaries and marshes have revealed the presence of similar spikes in the levels of Cs-137 and other fallout radionuclides. Robbins and Edgington (1975) and other researchers have demonstrated that these maxima correspond to the periods of peak atmospheric testing, and that it is therefore possible to accurately date these levels in the cores.

The presence of Cs-137 can be determined by gamma ray spectrometry (Robbins and Edgington - 1975). The gamma counting is done directly on oven-dried samples, using a lithium-drifted germanium (GeLi) detector to count the 661 KeV Cs-137 gamma rays. Counting is usually done over a long (24 hour) period because of the low levels of Cs-137 present.

Lead-210 is a naturally occurring isotope, and is an intermediate product in the Uranium-238 decay series. Its half-life of 22.3 years makes it ideal for the dating of samples less than 100 years old. An advantage of using this isotope is the low solubility of lead, and hence its low mobility in the sediments. The lead in the sample must usually be chemically separated to obtain sufficient concentrations if alpha- or beta-counting techniques are used (Rama, et al. - 1961). Such chemical separations are tedious, however, and may lead to greater errors. The use of low-level gamma ray spectrometry allows direct measurement of Pb-210 in sediment samples by counting of the 46.5 KeV gamma emissions, using a (GeLi) detector (Gäggeler, et al. - 1976). Long counting periods are again necessary, because of the low counting efficiency for Pb-210 in this energy range.

Atmospheric Pb-210 is produced by the decay of Rn-222, and is introduced into the soil by both dry and wet deposition. After the sediments are buried, no further input of atmospheric Pb-210 can take place. The activity of the Pb-210 in the sediments will therefore decline as a function of age, assuming that the lead in the sediments is immobile and insoluble. A steady, background concentration of Pb-210 (supported lead) is reached when the added Pb-210 has decayed and indicates Pb-210 is being produced within the core only by the radioactive decay of its progenitors in the U-238 decay series.

A major concern in dating these sediments will be problems of mixing and redeposition which may affect the distribution of the radionuclides. The extent of this problem cannot be ascertained until samples are collected and counted.

Gross alpha and beta activity of the sediment digestions can also be used as an indicator of the total amount of radionuclides present as a function of depth and sediment character. Radionuclides such as uranium, thorium and radium can be important contributors to total activity. It is anticipated that radionuclide activity in the sediment will increase as the mining area is approached going upstream simply as a result of the large uranium deposits in the area.

A sensitive (GeLi) gamma ray spectrometer is being purchased by the Research and Development Division of New Mexico Tech and will be available for the project. Instrumentation is also presently available for gross alpha and beta analysis. Several alpha spectrometers (ZnS fluorescence activated) are available and a Packard Tri-Carb liquid scintillation counter has recently been acquired by the Biology Department.

Historical records and archeological data will provide chronologic control on the probable age ranges of sampled channel and floodplain sedimentation units. Supplemental information on absolute ages of strata cored may also be obtained by using dendrochronology and other time-stratigraphic techniques developed for investigations of prior Indian and Spanish cultures of the Southwest region (Betancourt, 1980; Love, 1979).

Justification:

Since 1948, New Mexico has supplied more than 40% of the nation's uranium production, 99.8% of which came from the Grants Mineral Belt (Rautman, 1977). It is estimated that New Mexico has 52%

of the U.S. reserves of U_3O_8 at $ 50 per pound and 16% of the world's reserves excluding China and the U.S.S.R.(Perkins, 1979). As of 1978, there were 35 active uranium mines in, the Grants Mineral Belt, as well as five mills capable (by 1977) of handling about 21,000 tons of ore per day. Activity in the area is increasing rapidly; nine more mines are under development (Perkins, 1979), and a large mill to handle Gulf Mineral Corporation's Mt. Taylor mine is in the planning stage (Rautman, 1977). The locations of a number of these facilities are shown in Figure 1. In order to assess the impact of mining operations in the area, it is important to determine both the present and the past condition of the river sediments.

A growing population attracted primarily by the mining activity is located along the Rio San Jose from the Grants area to Laguna (see Figure 1), with the bulk of the habitation in the stream valley; it is important to ensure the safety of this population, as well as the local Indian population. Also, the sediments from the San Jose enter the Rio Grande system through the Rio Puerco and are eventually deposited in Elephant Butte Reservior. It has been estimated that the Rio Puerco contributes more than 50% of the sediment load to the Rio Grande in central New Mexico while carrying less than 16% of the water (Waite, et al. - 1972, Popp and Laquer, 1980). Excess metals associated with the sediments may be mobilized in the reservoir due to biological activity and the resulting anaerobic conditions occurring on the reservoir bottom.

It is imperative that regulatory agencies such as the New Mexico Environmental Improvement Division have data of this nature for their assessments and evaluations. The impact of the recent tailings pond spill at the United Nuclear mill near Churchrock, N.M. on the western slope may never be known because baseline data of this type are not available. The proposed research should be begun as soon as possible, since it is impossible to predict whether a similar incident may occur on the eastern drainage.

The work can be efficiently performed at New Mexico Tech because the study area is in close proximity to Socorro and since the investigators (as well as a number of other scientists at New Mexico Tech and at the New Mexico Bureau of Mines) already have a good deal of experience in the study area.

The New Mexico Bureau of Mines and Mineral Resources will provide support functions for the project as part of ongoing programs on the environmental geology of state energy lands.We hope that there will also be cooperation from the uranium industry, since the data will be very useful to them in their planning processes. We plan to contact uranium industry representatives when the project is approved. The project should also be of interest to Indian tribes in the study area and tribal councils will be informed of the project. It is hoped that they will cooperate in the sampling program.

This project will provide excellent training opportunities for two graduate students and two undergraduate students each year to work directly on environmental problems related to the important, energy-related uranium industry. The interdisciplinary nature of the study (involving chemistry, geochemistry and geology) will provide a broad perspective for the students.

Literature Review and Related Research

The use of radionuclides with relatively short half-lives, such as Pb-210 and Cs-137, to date recent sediments and establish anthropogenic inputs of metals is now well-established. This subject has been reviewed by Krishnaswami and Lal (1978).

Robbins and Edgington (1975, 1976) have used both Pb-210 and Cs-137 to establish anthropogenic inputs of lead from coal and gasoline use to Lake Michigan sediments. Bennington (1978) has used Pb-210 to determine lead fluxes in Long Island Sound, and Smith and Walton (1980) have used Cs-137, as well as pollen assemblages, to determine the sedimentation rate in a fjord in Quebec. Determination of Pb-210 by direct gamma ray spectrometry, by far the simplest method (and the method to be used in this study) has been discussed by Gäggeler, et al. (1976).

A large amount of work on the Grants Mineral Belt and other mining areas of New Mexico has been done at New Mexico Tech, both by the authors and by other members of the Institute. One of the investigators (C. Popp, 1980) is currently involved in a research project to evaluate the present surface water quality in the area and assess present mining effects. The project is funded by the New Mexico Water Resources Research Institute and is entitled "Potential Effects of Increased Demand for Energy. Transport of Heavy Metals, Nutrients, and Radioactive Species from the Grants Uranium Belt by the Rio San Jose - Rio Puerco Drainage System". The project report is due in October 1980, and information from the report will be very useful to this study.

Dr. Arpad Torma of the Metallurgy Department at New Mexico Tech is currently involved in a study of the radionuclides present in uranium tailings, and the results of his study will be incorporated into this project.

Many aspects of historical erosion-sedimentation activity in the Rio Puerco basin have been described in the literature. Of particular importance to this study are papers dealing with arroyo incision since the middle 1800's in the lower Rio San Jose and Rio Puerco valleys. Betancourt (1980), Bryan (1928), and Tuan (1966) provide good reviews of historical accounts of arroyo incision and discuss possible causes. A number of government agencies have investigated the hydraulic and geologic factors influencing erosion and sedimentation in existing channels throughout the Middle Rio Grande basin. Agencies involved in Puerco and Bernardo-Elephant Butte segments of the Middle Rio Grande include the Geological Survey, Forest Service, Soil Conservation Service, Bureau of Reclamation and Army Corps of Engineers. Representative accounts of their work on alluvial processes, deposits, and associated landforms are contained in reports by Aldon (1973), Burkham (1966), Culbertson and Dawdy (1964), Dortignac (1963), Happ (1948), Leopold and Miller (1956), Nordin (1963), Pease (1975), Poulsen and Fitzpatrick (1931), and Waite et al.(1972). Pertinent recent studies (unpublished) on the Rio Puerco include projects of the Corps of Engineers (Lower Puerco Dam site), Bureau of Land Management (Grazing Management Program), Colorado State University (channel form and process research) and University of New Mexico - Department of Geology (geomorphology of lower Puerco) and Technololgy Application Center (historical photo analysis).

The other investigator (Hawley) is currently involved statewide in the environmental geology program of the New Mexico Bureau of Mines and Mineral Resources. Major pertinent projects include: 1) studies of alluvial valley floors in areas of surface coal mining (mainly in the San Juan Basin); 2) a statewide mapping project for the U.S. Geological Survey of Quaternary age geologic features; and 3) cooperative studies of soil-geomorphic relationships with the Soil Conservation Service, USDA in Valencia and McKinley Counties.

Detailed field mapping and sampling techniques that will be used in this project are described in Hawley (1972), Hawley and Wilson (1965), and Gile et al. (1980). David Love, presently a graduate research associate with Hawley, is completing dissertation studies of fluvial geomorphic adjustments in the Chaco Canyon (National Monument) area of the Southern San Juan Basin. Results of his detailed studies (1979) of an entrenched stream system that is very similar to parts of the Rio Puerco and Rio San Jose also will be utilized in this project.

Facilities and Equipment

Laboratories and facilities at New Mexico Institute of Mining and Technology and the New Mexico Bureau of Mines in Socorro are available for this project. The well-equipped analytical and instrumental facilities include a Perkin-Elmer 403 atomic absorption spectrophotometer equipped with a graphite furnace and electrodeless discharge lamp system for trace metal analysis. A neutron activation analysis system is in use and a new neutron activation/gamma ray spectometer will be purchased in the summer of this year (1980). X-ray diffractometers are present in the Bureau of Mines and the Geoscience Department, and a rock grinding and sieving laboratory is located in the Bureau of Mines. Other standard equipment such as spectrophotometers is available in the Chemistry Department. Gross alpha counters are located in the Radon Laboratory, in the Physics Department and the Biology Department possesses a Packard Tri-Carb liquid scintillation counter.

Research Timetable

It is anticipated that the project length will be two years because of the number of samples within the sediment cores to be analyzed and the probable need for a second sampling after the first results are analyzed. The following will be used:

Timetable

1980 Oct.	1981 Jan.	Sept.	1982 Jan.	Sept.

Literature Search

Study Aerial Photos and Maps

Core Sampling-Rio Puerco Core Sampling-Rio San Jose

Mineralogical, Chemical and Radionuclide Analysis

Data Evaluation

Final Report

Personnel Support:

Principal Investigator-Dr. Carl J. Popp, Associate Professor, Department of Chemistry, New Mexico Tech. Joined faculty in 1969. Ph.D. in Inorganic Chemistry, 1968, University of Utah. Time commitment will be one month during the summer and one month during the academic year. Current research project was discussed previously(see pp. 5,8) and will terminate Oct. 1980. Also has students working on acid rain in New Mexico and geochemistry of molybdenum deposits in northern New Mexico.

Pertinent Recent Publications

1. Popp, C.J. and Laquer, F., "Trace Metal Transport and Partitioning in the Suspended Sediments of the Rio Grande and Tributaries in Central New Mexico", Chemosphere, Vol.9, 89-98 (1980).
2. Riese, A.C. and Popp, C.J., "Application of Solution-Mineral Equilibrium Chemistry to the Solution Mining of Uranium Ores", Grants Uranium Symposium-1979, to be published by the New Mexico Bureau of Mines, Nov. 1980.

Principal Investigator-Dr. John W. Hawley, Environmental Geologist, New Mexico Bureau of Mines and Mineral Resources; and Adjunct Professor, Department of Geosciences, New Mexico

Tech. Joined staff in 1977. From 1962 to 1977, geologist, Soil Survey Investigations, SCS, USDA, in New Mexico, Texas, and Oregon. Ph.D. in Geology, 1962, University of Illinois. Time commitment will be 2 months during year. Current projects include 1) identification of alluvial valley floors in coal-surface mine areas of the San Juan Basin; 2) preliminary evaluation of sites for hazarous waste disposal; 3) preparation of state map of Quaternary deposits and geomorphic features (Hawley et al.,1976, and in progress with U.S. Geological Survey; 4) investigations on late Cenozoic evolution of the Rio Grande rift (Hawley, 1978); and 5) serving as advisor to the Federal Cooperative Soil Survey (SCS, BLM, FS, and BIA) on soil-geomorphic relationships in New Mexico.

Pertinent Recent Publications

1. Hawley, J.W., Bachman, G.O., Manley, K., "Quaternary stratigraphy in the Basin and Range, and Great Plain provinces, New Mexico and western Texas," in *Quaternary Stratigraphy of North America*, W.C. Maheny,(Ed.) Dowden, Hutchinsen, and Ross, Inc., Stroadsburg, PA, 235-274 (1976).
2. Hawley, J.W.(compiler), *Guidebook to the Rio Grande Rift in New Mexico and Colorado*, Circular 163, New Mexico Bureau of Mines and Mineral Resources, Socorro, (1978).
3. Gile, L.H., Hawley, J.W., and Grossman, R.B., *Soils and Geomorphology in a Basin and Range Area of Southern New Mexico: Guidebook to the Desert Project*, Memoir 139, New Mexico Bureau of Mines and Mineral Resources, Socorro, (in preparation, 1980).

Institutional Units Involved:

This project will be undertaken by the New Mexico Institute of Mining and Technology and the New Mexico Bureau of Mines and Mineral Resources.

Impacts:

Existing baseline data regarding environmental conditions around the Grants Mineral Belt are very scarce. Because of the intense growth of activity in the area the possibility of other accidents such as occurred at the United Nuclear Mill will increase rapidly. There was no way to intelligently evaluate the United Nuclear accident and a great deal of effort involving both money and time was wasted in attempting to assess the results of the incident. Data from this proposal will be tremendously helpful to the State of New Mexico Environmental Improvement Agency and Federal agencies in their evaluation procedures. The public can then be presented with facts concerning the effects of the mining activity and judgments should be considerably less emotional. This assessment will help uranium companies to plan new facilities and will help local communities and Indian tribes understand the impacts of the uranium industry.

There is now intense interest and scrutiny of the uranium industry both by government agencies and by the public. This study can have a tremendous impact on the image of the industry and the regulations involved because historical data for the area will be available for comparison to present-day conditions. The affected area has experienced a large population growth in recent years and there should be concern for their health and safety.

We anticipate that two undergraduate work scholarships, one post-doctoral fellowship, and two graduate research assistantships, will be made available on this project.

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